2020 HINDSIGHT

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> Prediction is very difficult, especially about the future.
>
> —Niels Bohr

MENLO PARK—N. CALIF., 1 JAN. 2020—It seems appropriate, in this the final issue of *IEEE Internet Computing*,† to look back 20 years, to the turn of the millennium, for a retrospective on predictions about technology and its effects. So the Spider spent some time in the Internet Archive and came up with these sites. Of course, these pages were written when the dominant technology was text, augmented by still pictures, so you should find these pages amusingly quaint.

> "Future" is inherently plural.
>
> —William Gibson

Foresight Exchange • http://www.ideosphere.com/fx/main.html

How to predict the future efficiently? The Ideosphere proposed applying the principles of the stock market to the market for ideas. Based on an idea first applied by Robin Hanson to academic ideas (http://www.lucifer.com/~sean/IF/Exi8-IF.html), the Foresight Exchange set up a "futures" market in ideas: given a judicable proposition for a future date, one could buy and sell futures on that idea. (The actual Foresight Exchange used play money, as there were still legal restrictions on gambling at that time.) Hanson had argued that this was both a way to expose otherwise repressed scientific ideas and to establish real probabilities of the truth of scientific statements.

Checking out the Foresight Exchange on a random occasion in late 1999 (http://www.ideosphere.com/fx-bin/ListClaims) showed active markets in political events ("Gore wins '00 presidential vote," a 31-bid, 32-ask proposition—but who was Gore?), economics ("Apple Computer dies by 2005," bid 21, ask 33), math ("Goldbach's conjecture decided by 2020," bid 47, ask 70), sociology ("Bill and Hillary's marriage over by 2003," bid 30, ask 50—Hillary I remember, but who was Bill?), science ("Protein folding solved by 2010," bid 78, ask 79), and the utterly inane ("Astrology statistically significant by 2010," bid 9, ask 12).

In reality, the Foresight Exchange was mildly amusing but not an accurate predictor. Popularity isn't a particularly effective way to establish truth. It's also clear that if real money had been involved, the opportunities for insider trading would keep such a system from being viable (for example, plan to divorce Bill and make a run on the market).

> Change is good. You go first.
>
> —Dilbert (Scott Adams)

"Beyond the Information Revolution" • http://www.theatlantic.com/issues/99oct/9910drucker.htm

One of the more prescient forecasters of the society driven by information technology was management guru Peter Drucker. In this article from the online version of *Atlantic Monthly*, Drucker argued that the revolutionary effect of Internet technology would be on commerce, with the Internet becoming the major distribution channel for goods *and* services.

In the late 1990s, the Information Revolution seemed to be pushing society through unprecedented transformations, but Drucker compared the Information Revolution to the Industrial Revolution of the previous five centuries and argued that "the Industrial Revolution moved at least as fast in the same time span, and had probably an equal impact if not a greater one."

He found parallels in the development of the first 50 years of each, arguing that 1999 was like the early 1820s, 40 years after Watt's steam engine was first applied to spinning cotton. The Industrial Revolution produced a Moore's law-like effect on the price of textiles (the most important industrial commodity of the time) that lasted 50 years—prices fell 90 percent, and production in Britain alone increased 150-fold. Similar effects were seen in almost all other major artifacts. This had social effects of not only making consumer goods affordable to many more people, but also

- greatly simplifying and expanding the production of armaments,
- creating sufficient demand for cotton as to revive the dying institution of American slavery,
- giving rise to the "industrial working class" and the "entrepreneur,"and
- creating a "crisis of the family" by scattering both adults and children out of the home and into factories.

However, from Drucker's point of view, the key novelty and world trans-

†Yes, it's true. The IEEE Computer Society is finally retiring a magazine. For the past 10 years—what with the ubiquitous network, unbounded bandwidth, and free processing cycles—"Internet computing" has been as technically interesting as, say, plumbing, but politics and economics conspire to maintain institutions past their natural lifetimes.

former of the Industrial Revolution was the railroad, which produced the biggest economic boom in history to that time (though the current information and biotech revolutions certainly rival that result).

Railroads gave people mobility—for example, Drucker cited Braudel's theses that railroads had a nationalizing effect on both France and the United States. (In retrospect, it is surprising that Drucker didn't generalize this to the "internationalizing" effect that we've been seeing from information and communication technologies—railroads coalesced counties into countries. Today, info tech seems to be dissolving national boundaries.)

Drucker foresaw that e-commerce would be the railroad of the Information Revolution, the invention that would have quick and major social effects. He cites as an example the internationalization of trade, how lack of knowledge no longer protected local producers from competition—thus requiring most businesses to become globally competitive.

What Drucker did exceptionally well was describe the social effects of major economic changes and present the historic parallels to the printing and industrial revolutions. Drucker could see that other major economic effects paralleling the information revolution would occur, and pointed to fish farming and biotechnology as likely candidates, but failed to be more specific. (Do the current oceanic vegetable farms count as an instance of "fish farming"?)

He accurately pointed out that knowledge workers would be the source of economic power in the coming years, but incorrectly fretted that they would have a difficult time reaping the economic and social rewards of their work after the Internet stock bubble burst. (A modern investor, seeing the rewards knowledge workers command and faced with the difficulties of getting a positive return in an overcapitalized and aging society, must find such concerns curious. And in America, at least, social status has always followed economics.)

> "Within the past few months a group of physicists at the Bell Telephone Laboratories has made a profound and simple finding . . . , a method of controlling electrons in a solid crystal instead of in a vacuum. . . . Not only is the transistor tiny, but it needs so little power . . . that the size of batteries needed to operate portable devices can be reduced. In combination with printed circuits it may open up entirely new applications for electronics."
>
> —*Scientific American*, Sept. 1948

Centre for Quantum Computing • http://www.qubit.org/Intros_Tuts.html

In a conventional transistor-based computer, primitive memory elements are single-valued—each bit is either 1 or 0. In a quantum computer, a memory element exists in both states at once: testing for the value of the bit (or collection of bits) forces it into a state that matches the testing criteria. Since a bit can thus simultaneously hold two states, n bits can simultaneously hold 2^n states. Thus, theoretically, a quantum computer can find the goal state out of 2^n in a single operation—for example, factoring an n-bit number in a single step.

The late 1990s saw the first work in quantum computing, including descriptions of the first interesting quantum algorithms (factorization, critical for certain encryption algorithms) and initial demonstrations of single and dual-qubit quantum computers. Perhaps the best descriptions of quantum computing at the time were at this Oxford University site.

Readable papers on this site include

- "Towards Quantum Information Technology" (http://www.qubit.org/intros/nano/nano.html) by Simon Benjamin and Arthur Ekert, an overview of small-scale computing (which provides an interesting historical perspective of the current nanotechnological computing mechanisms);
- "A Short Introduction to Quantum Computation" (http://www.qubit.org/intros/comp/comp.html) by A. Barenco, A. Ekert, A. Sanpera, and C. Machiavello, with its clear illustrations of half-silvered mirror effects, and
- Andrew Sterne's "Quantum Computing" (http://www.qubit.org/intros/compSteane/qcintro.html), a lucid description of the fundamental nature of information in physics (for example, the speed of light is the limiting factor at conveying information) and a "name dropping" list of quantum achievements through 1997. This "paper" is actually the introduction to a longer (65-page) work (http://xxx.lanl.gov/format/quant-ph/9708022), a grand tour of information theory, computability, and their application in quantum computing.

For the more computationally inclined

- Braunstein's "Quantum Computation: A Tutorial" (http://www.sees.bangor.ac.uk/~schmuel/comp/comp.html) presented an in-depth (though by 1999, somewhat dated) explanation of a quantum algorithm for computing factorization.
- Reiffel and Polak's "Introduction to Quantum Computing for Non-Physicists" (http://xxx.lanl.gov/abs/quant-ph/9809016), which later became a *Computing Surveys* article, gave a more mathematical explanation of quantum computing.

The ensuing 20 years have seen an explosion of theoretical work in quantum computing, with algorithms introduced for many classes of problems and many interesting small demonstrations. However, success has so far eluded the builders of large-scale quantum computers. Conventional micro- and nanotechnologies have not stood still—we still await the first quantum computation that couldn't have been done more easily on conventional computers.

> Things are more like they are now than they ever were before.
>
> —Dwight Eisenhower

Paul Saffo • http://www.saffo.org

Paul Saffo was the director of the Institute for the Future (http://www.

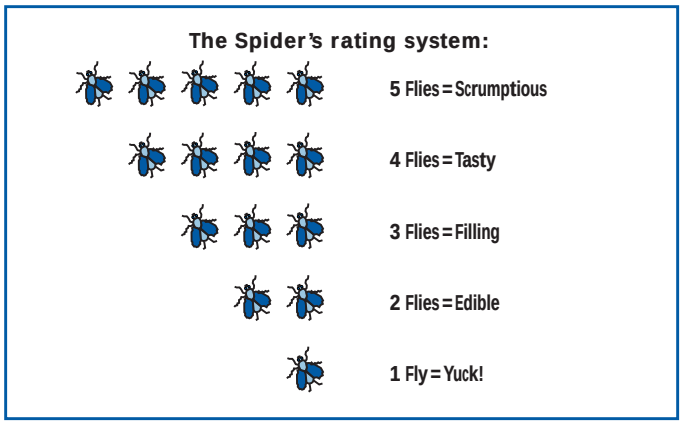
iftf.org), a forecasting organization in California that sold commercial predictions to businesses. Back at the turn of the millennium, Saffo was a frequent choice when the media needed soothsaying. While the Institute sold its work, Saffo kept his own Web page with a few of his essays.

In his essay on "disintermediation" (http://www.saffo.org/disinterremediation.html), Saffo argued that the then-current worries about cutting out the "middleman" weren't justified. He suggested instead that emerging information technologies were lengthening the chain of intermediaries between producers and consumers. He glossed over the point that it wasn't the cutting out of intermediaries per se that was so worrisome, but the cutting out of particular intermediaries that made those intermediaries unhappy (and willing to resort to political rather than economic mechanisms to protect their interests.) Saffo also missed the point that even though new and sometimes longer intermediary chains may arise under information technology, the total return for intermediaries declined. But, as usual, it was all about whose ox was being Gored.

In his essay on "sensors" (http://www.saffo.org/sensors.html), Saffo looked at the decade-long steps from microprocessors (for cheap processing) through lasers (for inexpensive storage and communication), and correctly forecast the increasing role of microsensors in society starting in the first decade of the twenty-first century. (Heavens knows, nowadays it is hard to find anyplace where you won't be watched by something.) I guess I was a little surprised that he didn't carry his projections further to the economical effectors that have effected so many things over the past 10 years—though since they really have to move atoms in space, their development has taken longer than the canonical Saffo decade, and Saffo tended not to look more than 10 years into the future.

For the record, Saffo's 1991 essay on the coming decade (http://www.saffo.org/millennium.html) predicted a 1990s dominated by "new-age" crazies, not the Internet gold-rush. Guess you can't win them all.

Here in North California, one of the best predictors of tomorrow's weather is today's weather. Saffo's forecasts were marked by well-grounded insights and lacked sensationalism. Sort of a formula for being more accurate but less exciting and consequential.



> On the other hand, all of this might be seen as groundless poppycock, as nothing more than what happens when silly science-fiction-addicted minds splice sloppy and wishful thinking together into an incoherent goulash.
>
> — Douglas Hofstadter

"When Will Computer Hardware Match the Human Brain?" • http://www.transhumanist.com/volume1/moravec.htm

In contrast to Saffo's conservatism, Hans Moravec took, shall we say, a more imaginative tone in this well-written and entertaining article. Moravec, a research scientist in the Mobile Robot Lab at Carnegie Mellon University, argued that once enough processing power was assembled, artificial intelligence would follow directly. Generalizing from the processing required for vision and the size of the retina, Moravec argued that "matching overall human behavior" would take about 100 million MIPS and 100 million megabytes of computer power.

Moravec believed that learning was essential for forming human-quality intelligence: "The small nervous systems of insects and other invertebrates seem to be hardwired from birth.... The few-hundred-million-bit insect genome is enough to specify connections of each of their hundred thousand neurons. Humans, on the other hand, have 100 billion neurons, but only a few billion bits of genome. The human brain seems to consist largely of regular structures whose neurons are trimmed away as skills are learned...."

Though processing power has increased at a faster rate than predicted in Moravec's article, and computers are demonstrating some quite impressive skills, virtually no one today would ascribe general intelligence to them. Part of this is, of course, Tesler's law—if we can describe how it's done, then clearly it's not intelligent. More importantly, though, in AI, the "knowledge level" has not progressed at nearly the rate of Moore's law, mere processing power does not imply architecture, and even evolutionary kinds of learning experiments have had to proceed at a clumsy, reality-limited pace.

DEAD TREES

Of course, the late 20th century was when people still tried to profit from their writings by killing trees. So not all interesting predictions were immediately available on the Web—for some, you had to get the actual hard copy. Such objects were called "books."

The Age of Spiritual Machines: When Computers Exceed Human Intelligence

by Ray Kurzweil (Viking, New York, 1999)

The main thesis of this book was that we'd have machine intelligence by about 2030—10 years from today.

Kurzweil echoes Moravec's arguments about the declining cost of computation, complementing his text with data and graphs showing an accelerating Moore's law effect going back to Hollerith. (We now understand the acceleration of Moore's law to be a function of applying the improving technology to the technology of creating the base technology—that is, faster microprocessors make it easier to design new microprocessors and build semiconductor fabrication equipment.)

He augments the acceleration argument with arguments about novel computational technologies such as nanotech and quantum computers.

The strength of this book is the insight into advances in user interfaces. (Kurzweil, after all, made his mark with speech-recognition systems.) The book's weaknesses are the naive jump from faster machines to intelligence, the carefree generalization from focused performance to general skills, and the blithe disregard for economics. In Kurzweil's world, humanity keeps getting richer and happier with nary a bump in the road. (See Drucker, above, for a more thoughtful analysis of the consequences of change.)

Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by its Inventor

by Tim Berners-Lee with Mark Fischetti (HarperSanFrancisco, New York,1999)

Turning from the outrageous to the restrained, we conclude with Tim Berners-Lee's book, the first three quarters of which is a history of early development of the Web. The primary author is cast as a determined, conscientious, hardworking visionary—generous with credit to all who aided in the struggle, and nary a bad word about anyone else. Berners-Lee comes off as the Edison of his day, understanding the need to bring together generation, transmission, and device (http://home.nycap.rr.com/useless/lightbulbs/litebulb.html), but not as the inventor of hypertext or networking.

This part reads like an award acceptance speech, with its care in citing every person or program along the way. It's also about as exciting as an awards acceptance speech. Books about technological development don't have to be tedious (remember *Soul of a New Machine*). This one is.

In the last quarter of the book, Berners-Lee turned to his view of the future. He foresaw a pervasively connected network of computers, where Web documents were computer understandable (expanding on RDF and XML), and much of the detail of human life was handled by inter-machine communications performing increasingly complex semantic analysis.

What was missing in this late twentieth-century view was a departure from the interfaces of the time—Berners-Lee thought in terms of URLs and clicking on icons, rather than "content centered" and contextual indexing schemes, and contextual interfaces.

He was right about the disappearance of locality for data, but that seems like a minor issue with today's networks and datastores. He correctly foresaw the volume of automatic agents that have emerged, but these agents have (perhaps inevitably) submerged into the fabric of social interactions, rather than being their focus. Software agents are currently as central to people's lives as thermostats were to Berners-Lee's peers in his youth.

While vast amounts of data are now exchanged over the network, greased by common protocols and conventions, even in 2000 vast amounts of data were exchanged over networks, greasing the economic engine, though perhaps less efficiently.

> The best way to predict the future is to invent it.
>
> —Alan Kay

What's notable about the predictions of 1999 is how, on one hand, they so readily capture technological progress while, on the other, they so glibly miss the effects of this progress on the texture of life.

Economically, people as a whole are wealthier, but much of that wealth is based on knowledge, and for many it is as continuous a struggle to maintain that knowledge as it was for their great-grandparents to keep food on the table and a roof overhead by physical labor.

In the political arena, information technologies have inspired and wrought changes both large and small. Political speech, for example, is generally freer than it was when freedom of the press was available only to those who could afford a printing press. (This started to change in the 1990s, when the Web enabled everyone and their grandmother to become a publisher.)

Political institutions tend to be fairer—the result of greater access to the legislative process, the replacement of gerrymandering with algorithmic processes that favor the most compact districts (subject to other well-defined constraints), and the remarkable success of campaign contribution reformation laws (inspired by Internet cybercash) that allow unlimited anonymous donations but make it a crime (bribery) to reveal them. As national borders and identities dissolve in the flow of commerce and culture around the globe, the twentieth-century nation-state is visibly becoming less relevant and having an increasingly hard time extracting the tax revenues to maintain its existence.

Emotionally, however, the populace seems more fragile, as it is buffered by the easy accessibility that the technology enables, the general lack of privacy, and the rapid pace of change. It's a good thing that psychiatric programs are so inexpensive, because otherwise many couldn't cope. ■

Farewell

Please note that, much to his editors' dismay, the Spider took a sabbatical after the first issue of the year 2000.

The Online Tourist

You'll find past issues of the Arachnoid Tourist in the *IC Online* archives.

http://computer.org/internet/arch.htm